IMPLICATIONS OF BYCATCH REDUCTION STRATEGIES FOR THE ECONOMIC VIABILITY OF MIXED FISHERIES

Vincent MARTINET, INRA, vincent.martinet@grignon.inra.fr
Olivier THEBAUD, Ifremer, olivier.thebaud@ifremer.fr

ABSTRACT

There is growing recognition worldwide that the impacts of fishing on non-targeted components of marine ecosystems should be included in the assessment of fisheries sustainability. This leads to the inclusion of new constraints in evaluations of the long-term bio-economic performance of fisheries. In this paper, we analyze the implications of such constraints based on the case of bycatch of juvenile hake in the Bay of Biscay (ICES area VIIIa,b) trawl fishery for nephrops. The analysis is based on a discrete time model of the trawl fishery including an age-structured representation of stock dynamics, with uncertainty. We define sustainability using the viability framework of analysis: viability objectives are represented as constraints which relate to the economic status of the fishing fleet and to the biological status of fish stocks. We include an ecological constraint defined as a minimal target threshold for the recruitment of mature hakes, which is related to the fishing mortality induced by trawlers on juvenile hake. Based on stochastic analysis, we define the probability that both economic and ecosystemic constraints are met, as a function of the level of these constraints. We use the model to assess the sustainability of the fishery under different scenarios as regards bycatch reduction strategies.

Keywords: Sustainable fish eries, management procedures, stochastic viability

INTRODUCTION

Excess capacity of global fishing fleets leads to the capability for these fleets to considerably alter the size of both exploited fish populations and other species. Present political objectives for fisheries management include stopping overfishing, rebuilding overfished stocks, minimizing bycatch and protecting essential fish habitats. The European Commission and the FAO emphasize the importance of an ecosystem-based framework for fisheries management (Garcia et al., 2003). The purpose of such integrated approaches is to provide sustainable management tools that simultaneously take into account biological, social and economic objectives. However developing an operational framework for an ecosystem-based approach to fisheries management is technically difficult, as it requires taking into account several dynamics (biological, economic and social), their interactions, and a large degree of uncertainty. An important issue is to develop this approach without excess complexity in the models used to describe fisheries (Charles, 2005). One way of escaping from this excess complexity is to extend the use of single species performance measures and references points, by taking into account specific interactions with non-targeted species.

Performance measures and reference points for the management of target species are now widely used in fisheries (ICES, 2003a,b). For example, the International Council for the Exploration of the Sea (ICES) develops management tools -- the so called precautionary approach -- based on reference points *Blim* (and *Bpa*) and indicators *Flim* (and *Fpa*), focusing respectively on the spawning stock biomass (SSB) and fishing mortality of targeted species. From a general point of view, limit reference points define cut-off points below or above which recruitment overfishing and/or risk of stock collapse is unacceptably high. De Lara et al. (2007) interpret these thresholds as constraints that the dynamic fisheries system must satisfy to remain perennial. Applying the viability framework of analysis, they show that the ICES precautionary approach is sustainable if and only if the lowest possible sum of survivors in a fished stock (weighted by growth and maturation) and newly recruited spawning biomass, is above *Blim*.

The ICES precautionary approach is designed for single species management. A first step in moving towards an ecosystem-based fisheries management framework is to expand single-species approaches centered on the target species, by considering non-target species impacted by fishing (Hall and Mainprize., 2004). We consider such an extended approach applied to the Bay of Biscay (ICES fishing areas VIIIa and VIIIb) Hake-Nephrops mixed fishery. This fishery has major economic importance both at the French regional and national scale. The Bay of Biscay hosts one of the most important nurseries of the Northern stock of Hake (ICES, 2003a). In recent years, estimated fishing mortality of Hake was just above the fishing mortality corresponding to the precautionary approach (*Fpa*) and the Hake spawning stock biomass has declined until stabilizing to a low level in the early 90's, raising serious concerns regarding the stock's viability. A recovery plan was enforced in 2004. Hake constitutes an important by-catch in the Bay of Biscay Nephrops fishery. Nephrops fisheries induce at least half of the fishing mortality of the three first age groups of Hake (immatures). A recovery program concerning the Hake population must thus take Nephrops fishing activity into account. According to Drouineau et al. (2006), it is urgent to find new Management Procedures in order to achieve sustainability of this mixed fishery. An important issue is thus to examine the possibility to define a viable exploitation of the Bay of Biscay Nephrops while limiting the by-catch impact on Hake.

Butterworth et al. (1997) define a Management Procedure (MP) as a set of clearly defined rules, which translate data from a fishery into a regulatory mechanism (defining for example Total Allowable Catches, or Fishing effort, each year). The main objective of a MP is to define a harvesting strategy guaranteeing allowable catches that provide acceptable stability to the fishing industry while at the same time resulting in biological risks that are acceptable in terms of scientifically established norms (Geromont et al., 1999). According to Kell et al. (2005), stocks may crash at fishing levels that standard stochastic projections would suggest were safe. It is thus necessary to develop models that capture the characteristics of fisheries dynamics, and develop management procedure that are robust to a broad range of uncertainty. Notwithstanding the difficulty to define MP that are robust to uncertainty, another problem faced by MP evaluation is to encompass a sufficiently wide range of plausible scenarii for resource status in the face of high variability of resources, and to try to manage conflicting fisheries in a joint MP (Geromont et al., 1999). From a more general point of view, the issue is to take into account conflicting objectives in an uncertain environment.

When technical interactions exist between the catches of two species, joint management procedure are needed to provide Total Admissible Catches (TAC) recommendations for both species simultaneously. This is for example the case in South African pelagic fisheries where juvenile pilchard are taken as bycatch in the anchovy fishery (De Oliveira and Butterworth, 2004). This is also the case in our problem, where Hake is a bycatch to the Bay of Biscay Nephrops fishery.

In this paper, we propose to enlarge the approach to Management Strategy Evaluations applied to such contexts. The analysis aims at:

1. defining a theoretical framework that makes it possible to analyze trade-offs between sustainability objectives in fisheries management, when environmental uncertainty occurs;
2. applying this framework to the more specific case of technical interactions in fisheries;
3. analyzing possible management options, such as increased selectivity, in a particular fishery model.

We propose to represent the set of sustainability objectives (including economic and ecological objectives of fisheries management) by a set of constraints on indicator levels. In a multi-criteria framework, we seek to identify management strategies that allow to respect all the constraints over the planning horizon, i.e. to achieve all of the sustainability objectives in the long-run. We do not give priority to an objective over the others. As we are interested in analyzing the robustness of management strategies to uncertainty, we use the viability approach in a stochastic framework, and examine the probability that sustainability objectives are achieved over a finite time horizon.

To illustrate the general approach, we propose a viability analysis of the Hake-Nephrops fisheries. We examine how to conciliate economic objectives for the Nephrops fishery while taking into account the impact of its fishing activity on the Hake population. Two sustainability objectives are considered: (i) on one hand, a minimal profit defines the economic viability of the Nephrops fishery; (ii) on the other hand, viability of the Hake stock is defined in terms of biological limits allowing reproduction of the fish stock. The recruitment of mature Hake in the fishery is used as a proxy indicator of this viability constraint.

We develop a discrete time dynamic model with uncertainty in recruitment. In a stochastic framework, we measure viability by the probability that there exists feedback controls (management procedure) ensuring that constraints are satisfied along a given finite horizon. This viability probability obviously depends on the levels of these constraints. We perform a Monte Carlo estimation of this probability as a function of the constraints level. This allows us to measure trade-offs in viability constraints.

We then analyze the implication of a change in the exploitation diagram of the Nephrops fishery (for example due to a change in fishing gear) in order to reduce bycatch by increasing selectivity. For that purpose, we examine the viability probability associated with the new exploitation pattern.

THE BIOECONOMIC MODEL

The population dynamics models and economic dynamics

TWe model the biological dynamics of two species: European Hake (*merlucius merlucius*) and Nephrops (*Nephrops norvegicus*). These two species are represented as aged-structured stocks (Gulland, 1967; Xiao, 2007), with A age groups for each stock (in this case, 9 age groups for each stock).

The abundance of each species is defined by a number of individuals in age groups $a=1,\dots,A$. We denote by $N^S(t)$ the abundance of species s at year t, where $s=h,n$ respectively for Hake and Nephrops: $N^S(t)$ is a vector whose component $N^S_a(t)$ represents the abundance of the a-group.

The dynamics of the resource is described by

$$N^S(t+1)=G(N^S(t),u(t),w(t)) \tag{1}$$

It depends on the resource stock, the decision parameter $u(t)$ which represents fishing effort of the Nephrops fleet, and the uncertainty parameter $w(t)$.

The first group (a=1) is composed of the new recruits to the stock. The number of recruits may depend on many factors, including the size of the genitor stock and some environmental factors. This leads to uncertainty on recruitment. To represent this uncertainty, we define recruitment as a function of stock biomass and an uncertainty parameter $w(t)$:

$$N^S(t+1)= \mathrm{f}^S (N^S(t),\mathrm{w(t)}). \tag{2}$$

For age groups from 2 to A-1, the number of individuals of age a in year t+1 depends on the number of individuals of age a-1 in year t that survived. We distinguish the natural mortality rate M^S_a of species s at age a, and the fishing mortality $F^S_a(t)$. The dynamics read

$$N^S_a(t+1) = N^S_{a-1}(t)\ (1 - M^S_{a-1} - F^S_{a-1}(t)) \tag{3}$$

The A age-group is a ``plus-group'' composed by the survivors of both *A* and *A*-1 age-groups at the previous period. Its population evolves as follows

$$N^s_A(t+1) = N^s_{A-1}(t)\,(1 - M^s_{A-1} - F^s_{A-1}(t)) + N^s_A(t)\,(1 - M^s_A - F^s_A(t)) \tag{4}$$

The Nephrops fishery targets Nephrops but catches Hake as bycatch. It thus induces a fishing mortality $F^n(t)$ and a fishing mortality $F^h(t)$. Hake is also caught by other fleets, leading to an additional fishing mortality $F^{h\#}(t)$ considered constant in the present analysis. Fishing mortalities at year *t* thus vary with the fishing effort of the fleet targeting Nephrops. This effort is defined with respect to a reference fishing mortality $F^{sref}(t)$, and an effort multiplier $u(t)$. We thus have

$$F^n(t) = u(t)\,F^{nref} \tag{5}$$

$$F^h(t) = u(t)\,F^{href} + F^{h\#} \tag{6}$$

We are interested in two categories of catches by the Nephrops fishery: Nephrops catches that generate the gross return of the fleet, and catches of juvenile Hakes that induce ecological (and economic) losses (hake bycatch, being discarded, generates no return to the nephrops trawling fleet).

The catches $C^s_a(t)$ of fish belonging to the *a* age group in year *t* are defined by

$$C^s_a(t) = F^s_a(t)\,N^s_a(t) \tag{7}$$

Part of these catches are discarded according to discard rate d^s_a. For the estimation of discard rates we refer to Talidec et al. (2005) and ICES (2003a,b). Considering the mean weight at age w^s_a for each species, and the price per kilo for the corresponding market class p^s_a, we can compute the gross return of the Nephrops fishery, and define the economic profit at year *t*, given the costs $Q(t)=u(t)q^{ref}$ where q^{ref} are the fishing costs associated to the fishing effort of the reference year. The profit is defined by

$$\begin{aligned}\pi(t,N^n(t),u(t)) &= \Sigma_a\,[p^n_a\, w^n_a\,(1-d^n_a)\,C^n_a(t)] - Q(t)\\ &= u(t)\left(\Sigma_a\,[p^n_a\, w^n_a\,(1-d^n_a)\,N^n_a(t)\,F^{nref}] - q^{ref}\right)\end{aligned} \tag{8}$$

Sustainability objectives: viability constraints

We define sustainability of the fishery by taking into account economic objectives and the ecological impact of the Nephrops fishery on the Hake population. Sustainability is defined as the satisfaction of economic and ecological constraints dynamically.

De Oliveira and Butterworth (2004) define Joint Management Procedures of two fisheries with technical interactions by setting a TAC on the targeted species and a limit on the bycatch level for the other species (Total Admissible Bycatch, TAB). We argue here that the viability of the bycaught species will not depend on the absolute level of bycatch, but on a minimal recruitment of mature individuals in the fish stock, whatever the level of bycatch is. Also, we consider that the economic viability of the fishery will not only depend on target species catches (and thus on a TAC level), but on the profit derived from the fishery.

We thus define the following viability constraints for the fishery. On one hand, we consider that the Nephrops fishery is economically viable if profit is greater than a threshold π_{min}. This minimal threshold is the economic objective for sustainability. On the other hand, we consider that the fishery is ecologically viable if its impact on Hake biology is compatible with a minimum level of recruitment of mature Hake. The ogive of sexual maturity for Hake is as follows:

Age group	1	2	3	4	5	6	7+
% of mature individuals	0	0	0	0.2	0.6	0.9	1

The fourth age group of Hake is the first group to contain mature individuals. Given that bycatch of the first three age groups of Hake by Nephrops fishing vessels is important (ICES, 2003a,b ; Talidec et al., 2005), we define a target recruitment for the fourth age group of Hakes N^h_{min}. As the mortality of juveniles is mainly due to the Nephrops fishery, a constraint on recruitment of mature Hakes will induce a need to limit Nephrops fishing activity[1]. To be sustainable, the Nephrops fishery must thus satisfy the following conditions in any year t $(t=t_0,\ldots,T)$:

$$\pi\,(t,N^n(t),u(t)) \geq \pi_{min} \tag{9}$$

$$N^h_4\,(t) \geq N^h_{min} \tag{10}$$

If one of these constraints is not respected, the Nephrops-Hake mixed fishery faces a crisis situation, either from the biological or from the economic point of view.

STOCHASTIC VIABILITY AS A TOOL FOR MANAGEMENT STRATEGIES EVALUATION

We propose to examine the viability of management procedures with respect to both economic and ecological objectives. Both the objectives must be achieved over the planning horizon for the fishery to be said viable.

The purpose of Management Strategy Evaluations is to evaluate the consequences of management procedures with respect to the fisheries objectives. This includes evaluating the consequences of uncertainty by means of simulation tests and subsequently developing MP that are robust to this uncertainty in the long run (Geromont et al., 1999). The method consists in testing a particular management procedure in a great number of simulations over a given time period, each simulation representing a plausible ``state of nature'' (scenario), and in performing statistics over the simulation results to summarize the performance of the particular Management Procedure (De Oliveira and Butterworth, 2004). When comparing Management Procedures, their performance is considered to be best when the risk of reducing abundance to a low level is small, the variations in allowable catches from year to year are low, and average catches are high. To represent these objectives, statistics are thus computed regarding depletion risk, Total Allowable Catches variability, and average catch. As these objectives are often in conflict, choice of management procedure usually implies trade-offs between them.

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[1] The ecological constraint thus defined, based on this proxy indicator (recruitment of the fourth age-group), follows the analysis of De Lara et al. (2007) who examine the conditions for ICES management tools to ensure viable fisheries. Management decisions based on precautionary minimal biomass and maximal fishing mortalities, Bpa and Fpa, are viable if a minimal number of genitors is recruited each year, assuming this minimum number to be constant.

We propose to enlarge the usual Management Procedure Evaluation approach by using viability theory. To characterize the sustainability of the fishery, we use the viability approach (Aubin 1991). This framework allows us to study the consistency between inter-temporal trajectories and constraints in dynamic systems. It has been applied to the sustainability issue in Martinet and Doyen (2007), and to the study of fisheries sustainability and recovery processes in Martinet et al. (2007). It is advocated as a relevant approach to fisheries management in an ecosystemic perspective by Cury et al. (2005). We use this framework to to identify decision rules that make it possible to achieve sustainability objectives at all periods of the planning horizon, without giving priority of one of the objective, for example the TAC level. In the proposed framework, a management procedure will be preferred if it leads to a higher viability probability.

In the present analysis, we consider a finite time horizon. An exploitation trajectory is viable if both the economic constraint (9) and the ecological constraint (10) are satisfied for all $t=t_0,...,T$. We aim at defining Management Strategies that result in viable trajectories of the system, i.e. inter-temporal trajectories that respect the economic constraint (9) and the ecological constraint (10) through time. We adopt a stochastic approach by fixing a given probability P on the set of scenarios $w(.)=(w(t_0),...,w(T))$, representing the uncertainty inherent to our dynamic model representing the fishery.

We are interested in the definition of the probability to achieve viability goals from the initial state of the fishery $(N^h(t_0),N^n(t_0))$. For any couple of sustainability objectives $(\pi_{min},N^h{}_{min})$, we define the probability that there exists exploitation decision rules that make it possible to achieve sustainability objectives, and denote this probability $P(\pi_{min},N^h{}_{min})$.This measures the probability that the fishery will not face a crisis situation over the time horizon T. The policy objective is to define management strategies that maximize this probability. Hence, the approach seeks to identify both the probability to achieve a set of given sustainability objectives in the fishery, and the decision rule (management procedure) that maximizes that probability.

ANALYZING MIXED FISHERIES VIABILITY

In order to analyze the viability of the mixed fishery with respect to both economic and ecological objectives, we compute the viability probability associated with the objectives. Carrying out a sensitivity analysis on the level of the objective values then allows us to describe the trade-offs between:

- the economic and ecological objectives;
- the level of the objectives and the probability to achieve them.

We compute, for a range of economic and ecological viability objectives, the probability that viable decisions and inter-temporal paths exist, given the uncertainty on recruitment $w(.)=(w(t_0),...,w(T-1))$. This means that the computed probability is the probability that *one* of the possible management procedures leads to a viable fishery. To compute this probability, we must in theory simulate the consequences of all possible Management Procedures. We thus do not limit our study to the examination of the consequences of a particular management procedure, but can nevertheless identify the management procedure that maximizes the probability of a viable fishery, using the result of De Lara and Martinet (2008).

From an operational point of view, instead of analyzing all possible management procedures resulting in inter-temporal fishing effort $u(.)$ and inter-temporal trajectories $(N^h(t),N^n(t))$ starting from the initial biological state $(N^h(t_0),N^n(t_0))$, we use the fact that the greater the fishing effort, the greater the annual gross return, and the lower the remaining fish stock. We apply the result of De Lara and Martinet (2008), defining the management procedure that maximizes the viability probability of our problem, with reference to a limit harvesting strategy $u*$.

We define the minimum effort consistent with the profit target $\pi_{\min}$:

$$u^*(t,N^n) = \inf\{\, u \mid \pi(t,N^n,u) \geq \pi_{min} \,\}$$

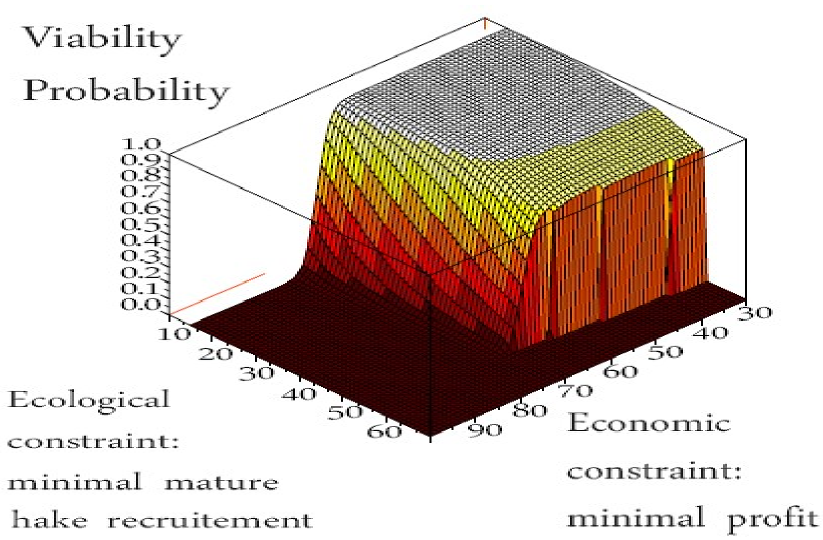
$$\Rightarrow u^* = \pi_{min} \Big/ \Big(\textstyle\sum_a \big[p^n_a\, w^n_a\, (1-d^n_a)\, F^{nref} N^n \big] - q^{ref} \Big) \qquad (11)$$

Numerical approach

We estimate the viability probability associated with various constraint levels by Monte-Carlo simulations, approximating probabilities by frequencies. As there are no established stock-recruitment relationships for the two species studied, we consider that the sequences $N^s_1(t_0+1), \ldots, N^s_1(T)$ for $s=h,n$ are independent i.i.d. sequences. Each $N^s_1(t)$ is supposed to follow a Normal distribution with estimated mean recruitment N^s_0 and standard deviation defined using available data.

We determine the viability probability on a range of constraints levels. For each couple of constraints levels, we generate 10 000 recruitment scenarii and check whether the minimal harvesting strategy satisfying the economic constraint (9) also satisfies the ecological constraint (10). We thus obtain the frequency of viable trajectories, which is an approximation of the viability probability. Results are presented on Fig.1.

Fig. 1: Viability probability for a range of sustainability objectives π_{min} and N^h_{min}



As expected, we observe on Fig.1 that the probability to have a viable exploitation decreases when the constraints levels π_{min} and N^h_{min} increase. Trade-offs between the sustainability objectives and the probability to achieve these objectives in an uncertain world can thus be quantified.

Moreover, our analysis makes it possible to define a set of management objectives with an associated risk (probability of success). We can define the set of sustainability objectives that can be achieved with a probability level greater than β. For example, the set of sustainability management objectives that can be achieved with a probability greater than β=0.9 is presented on Fig.2.

Fig. 2: Sustainability objectives that are achievable with a probability greater than 0.9

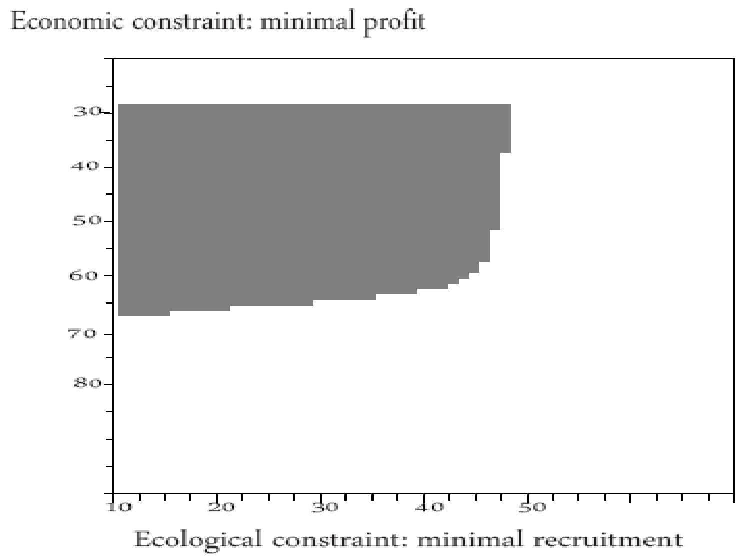


Fig. 2 illustrates the trade-offs in defining the ecological and the economic constraint: for the same probability of keeping the fishery within the specified constraints, increasing the tightness of ecological objectives (in our case, increasing the minimum recruitment of adult Hake) will imply lowering the economic viability constraint (in our case, lowering the minimum profit for the Nephrops fishing fleet). The trade-off is not constant with the level of the ecological constraint: as the strictness of this constraint is increased, keeping a high probability of ecological-economic viability will imply strong reductions in the minimum gross turnover. If the ecological constraint is set too high, it will not be possible for the fishery to be viable with the required probability.

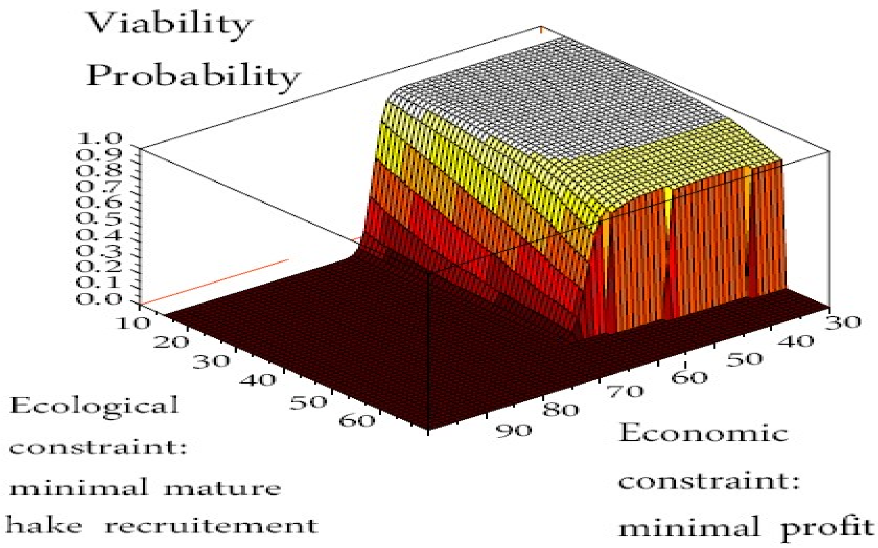
This analysis provides a description of the trade-offs in defining sustainability objectives for the fishery. One can not have at the same time high economic and ecological requirements and an important robustness to uncertainty. In particular, the current objectives for the Nephrops fishery of maintaining recent years profit while diminishing the bycatch of Hake is associated with a very low probability of achievement, hence little chances of success. In its present exploitation configuration, the fishery thus displays limited viability, based on our definition of viability objectives.

Alternative exploitation pattern

Based on our approach, we can assess the capacity of alternative management scenarii to contribute to maintain the fishery within the pre-specified economic and ecological constraints. In order to analyze a management procedure that aims at reducing the bycatch level, we consider the implication of a change in the exploitation diagram of the Nephrops fishery due to a modification of the selectivity of Nephrops trawls. This technical change entails a reduction of fishing mortalities on Hakes, but also reduces the catching efficiency on small Nephrops.

We define new fishing mortalities F^n and F^h of the Nephrops fishery for the two species, corresponding to the alternative selectivity of the Nephrops fishing fleet on both species. Fig.3 presents the viability probability associated with the same range of constraints as before, but with the new selectivity measure.

Fig. 3: Viability probability with an alternative selectivity pattern



The viability probability decreases when the selectivity of fishing gears is increased. This can be explained by the fact that imposing gear restrictions in order to improve selectivity implies a reduction of both bycatch AND catch. This entails lower profit for the Nephrops fishery. As our viability analysis is based on both ecological and economic objectives, the economic sustainability objective will be harder to achieve, and the overall viability probability is reduced.

An additional consequence which the analysis allows to illustrate is that if the economic objective is not achieved, the fishery will face an economic crisis. Fishers are thus bound to be strongly opposed to gear restrictions and effort limitation, as such measures would reduce their profit in the short run. From a general point of view, increases in the selectivity of fishing gear will result in higher stock levels in the medium term, and the short term costs will often be lower than the long-run benefits. Nevertheless, given the multi-dimensional nature of constraints applying to fisheries recovery programs, and in particular the importance of acceptability constraints (Martinet and Thébaud, 2008), a management program based on a reduction of bycatch will require compensation mechanisms to deal with the initial decrease of profit, if one wants the program to succeed.

CONCLUSION

In this paper, we propose to use the viability framework as a tool to evaluate Management Strategies in fisheries. The approach is based on the definition of a set of constraints representing the sustainability objectives of the fishery, and on the definition of management decisions that allow the fishery to satisfy all the constraints at all times. Uncertainty is included by adopting a stochastic framework of analysis. We define the probability that a set of sustainability objectives are achieved, and the management procedure that maximizes that probability. The viability probability represents the possibility for the fishery to avoid a crisis over the planning horizon, that is, the probability to meet all the objectives dynamically, without giving priority to any one of them.

We apply this framework to analyze the sustainability of a mixed fishery, where technical interactions exist between the catches of two species. As a case-study, we consider the Bay of Biscay Nephrops fishery, which targets Nephrops and catches juvenile Hake as bycatch, jeopardizing the viability of the Hake fishery. We characterize the sustainability of the fishery using two indicators: On one hand, we consider that the Nephrops fishery is economically viable if the profit is greater than a minimal threshold; on the other hand, we consider that the fishery has a sustainable ecological impact on the Hake species if the abundance of the fourth age-group of Hake is higher than a threshold. This latter constraint is based on the viability analysis developed by De Lara et al. (2007), and on the fact that the fourth age-group is the first to include mature Hake.

We treat the levels of the economic and ecological constraints as parameters, and develop a sensitivity analysis based on these two parameters. Doing this, we define the viability probability for a range of sustainability objectives. This allows us to exhibit the trade-offs between sustainability objectives, and between the sustainability requirements and the probability that these goals can be achieved. More specifically, we show that the higher the sustainability objectives, the lower the viability probability. We also show that, if one wants the sustainability objectives to be achieved with a minimal probability (e.g. 90%), one must choose these objectives within a reduced set. A major difference between our approach and standard Management Strategy Evaluation is that it is not based on statistics computations on the indicators (for example mean of the catches, variance of TAC...). In particular, the viability constraints have to be respected at any time for the fishery to be said sustainable.

In our particular case study, we show that the configuration of the fishery is lowly compatible with the objectives of having a high profit and low bycatch. We examine the impact of a measure increasing the selectivity of fishing gear in order to reduce bycatch. It appears that such a measure is associated with a lower probability to satisfy the viability constraint, as short term costs jeopardize the economic viability of the fishery. This emphasizes the necessity to define regulated transition phases in the definition of recovery programs.

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ENDNOTES

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